BETTER SCHEDULE PERFORMANCE ASSESSMENTS DERIVED FROM INTEGRATED MASTER PLAN-REFERENCED SCHEDULE METRICS

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The integrated master plan (IMP) provides a better structure than either the work breakdown structure (WBS) or organizational breakdown structure for measuring actual integrated master schedule (IMS) progress. The author posits that improved understanding of schedule performance and better identification of program risks result when an IMP structure is evaluated in addition to the earned value management-mandated IMS WBS structure. The article examines how the "Hit-Miss" index, baseline execution index, and critical path length index (CPLI) were used to evaluate the life-cycle performance of a 12-month, 900-task IMP program event. CPLI, the author concludes, is subject to interpretation and must be evaluated against four caveats: duration remaining, total float including schedule margin, schedule compression, and schedule avoidance.

Keywords: *Baseline Execution Index (BEI), Critical Path Length Index (CPLI), Earned Value Management (EVM), Integrated Master Plan (IMP), Integrated Master Schedule (IMS)*

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NGA-CONSOLIDATION-DEADLINE

Since 2005, the National Geospatial-Intelligence Agency (NGA) has been tasked under the Base Realignment and Closure Act to consolidate all Washington, DC, metropolitan area facilities to a standalone campus currently called NGA Campus East (NCE) by September 11, 2011. The U.S. Army Corps of Engineers is currently managing the construction of NCE at the Fort Belvoir, Virginia, Engineering Proving Grounds (NGA, 2010). In addition to the NCE facilities, NGA has awarded additional contracts for the installation of communication, hardware, and software systems necessary to support the NGA mission at the new facility. This article examines the schedule performance reported from one of these contracts. The contract included full earned value management (EVM) implementation, and the reported data came from an Electronic Industries Alliance (EIA)-748B-compliant earned value management system (EVMS) (Government Electronics and Information Technology Association [GEIA], 2007).

The NGA program management team has included EVM as one tool to effectively manage program risk, technical scope, cost, and schedule. This contract's effort is built around an integrated master plan (IMP)[1] consisting of 11 major program events (PE),[2] 43 significant accomplishments,[3] and 201 accomplishment criteria.[4] From this IMP, a 6,000-line integrated master schedule (IMS) has evolved and continues to grow each month as the contract matures. A product-oriented work breakdown structure (WBS) and a corresponding EVM performance measurement baseline (PMB) resulted from the IMS. Integrated baseline reviews (IBR) were held in month 2 and month 6 of the program, and all IBR-related issues were resolved by month 13. The NGA EVM Center of Excellence (EVM COE) is responsible for program oversight and was challenged to create a set of pure, "straightforward" IMS metrics unrelated to EVM that would provide NGA leadership with accurate assessments of schedule progress.

The EVM COE augmented the contract-level acquisition, technology and logistics (AT&L) tripwire schedule metrics to improve their utility for assessing NCE contract schedule progress. Initially, the EVM COE examined reporting on all 14 of the Defense Contract Management Agency (DCMA)'s 14 point schedule assessment[5] metrics (Treacy, 2010) using the proposed 62-element Generally Accepted Scheduling Principle (GASP),[6] a quick-look schedule assessment (Meyer, 2010). Both proved to be far too detailed and intricate to address the straightforward challenge from NGA leadership. In 2006, DCMA standardized a set of EVM and schedule metrics for the Defense Acquisition Executive Summary (DAES) process known as the AT&L tripwire metrics. A subset of DCMA's 14 point schedule assessment metrics is included as AT&L tripwire met-

rics. The two primary and seven secondary metrics are designed to surface problems early for effective issue resolution (Kester, 2007). The baseline execution index (BEI) (which measures work progress) and the critical path length index (CPLI) (which measures efficiency associated with completing a milestone) are two of the secondary AT&L tripwire metrics directly related to schedule performance. Although not directly reported as a tripwire metric, the DCMA BEI tripwire briefing also reports the closely related "Task Hit/Miss Percentage" or the "Hit-Miss" index. These three metrics were the starting point for NGA's straightforward schedule assessment. Initially, the EVM COE computed these metrics only at the contract level and found them to have limited utility. Department of Defense (DoD) policy and the IMS data item description require the IMS to be delivered in a product-oriented WBS format (DoD, 2006). Since most of the contract's PEs cut across multiple WBS elements, computing WBS-related BEIs and Hit-Miss indexes revealed little about progress to the next PE. Considering that September 2011 was many months away, the critical path to that date was mostly controlled by EVM summary-level planning packages[7] or external milestones, making a contract-level CPLI at best misleading and unreliable. To accurately assess contract progress, the EVM COE computed IMS schedule metrics using an IMP structure and redefined the CPLI tripwire metric to include schedule margin.[8]

After reviewing an actual 12-month IMP PE life cycle, five metrics emerged that best defined schedule performance and status: contract-level Hit-Miss index, PE Hit-Miss index, contract-level BEI, PE BEI, and the PE CPLI. The EVM product-oriented WBS provided little insight into actual schedule performance because each reporting-level WBS element supported multiple PEs. The IMS data item description requires the IMS to be vertically traceable to the IMP, but it includes the caveat "(if applicable)" (DoD, 2005b). NGA contractors are required to map their IMS tasks and milestones to the IMP. This allows the schedule to be sorted by IMP PEs, IMP significant accomplishments, as well as the EVM product-oriented WBS and contract organization structures. Because the contract PEs were sequential in nature, the program management team's assessment focused on the next IMP PE or, in one case, the next two PEs because they were being completed in parallel. The EVM COE Hit-Miss index uses the AT&L Hit-Miss equation to measure the percentage of the current month baseline tasks/activities actually completed (or Hit) on or ahead of their baseline schedule (Figure 1). The EVM COE uses the AT&L tripwire BEI equation to measure the cumulative efficiency with which actual work is accomplished when measured against the baseline (Figure 2). Different from the AT&L tripwire equation, the NGA CPLI equation includes recognition

FIGURE 1. "HIT-MISS" INDEX EQUATION

$$\text{Task Hit - Miss} = \frac{\text{\# of THIS month's tasks finished on or ahead of their baseline schedule}}{\text{\# of THIS month's tasks to be finished in the baseline schedule}}$$

Note. This current period metric measures the percentage of current month baseline tasks/activities actually completed (or Hit) on or ahead of their baseline schedule (Hurley, 2007).

FIGURE 2. BASELINE EXECUTION INDEX (BEI) EQUATION

$$\text{BEI} = \frac{\text{\# of Baseline Tasks Actually Completed}}{\text{\# of Baseline Tasks Scheduled to be Completed}}$$

Note. This cumulative metric measures the efficiency with which actual work has been accomplished when measured against the baseline (Hurley, 2007).

of IMS schedule margin.[9] By dissecting the CPLI over the entire life cycle of an IMP PE, the program management team discovered that unlike the Hit-Miss and BEI metrics, they could easily influence the value of the CPLI metric (Figure 3). To truly understand a CPLI, four schedule caveats must be determined: duration remaining, float[10] and margin, schedule compression,[11] and schedule avoidance.[12] The following discussion presents a hypothetical schedule to review and explain these metrics and CPLI schedule caveats.

FIGURE 3. CRITICAL PATH LENGTH INDEX (CPLI) EQUATION

$$\text{CPLI} = \frac{\text{Remaining Duration + Float + Schedule Margin}}{\text{Remaining Duration}}$$

Note. Indexes the remaining duration to an IMP PE's current finish (*or to the original baseline finish, whichever is greater*) plus float duration plus schedule margin against the remaining duration. Float duration is always measured to the IMP PE's baseline finish date.

Method

The NGA schedule metrics and rationale for the four CPLI caveats can best be explained by reviewing the progress of a hypothetical schedule. Figure 4 is a hypothetical baseline schedule consisting of summary-level tasks, work tasks, one margin task, two PE milestones, and a start milestone. The network[13] schedule to PE No. 1 includes a critical path string and a high-risk path string, each networked to the PE No. 1's multistring margin task. Remember that

FIGURE 4. BASELINE SCHEDULE

	Unique ID	Name	Baseline Finish	Actual Finish	Baseline Duration	Duration	Schedule Compression	Float	Slip
1	14	Start Milestone	Mon 1/4/10	NA	0 days	0 days	0 days	0 days	0 days
2	**1**	**Critical Path Summary Task**	**Fri 4/16/10**	**NA**	**75 days**	**75 days**	**0 days**	**0 days**	**0 days**
3	2	10-Day Work Task A1	Fri 1/15/10	NA	10 days	10 days	0 days	0 days	0 days
4	3	20-Day Work Task A2	Fri 2/12/10	NA	20 days	20 days	0 days	0 days	0 days
5	4	10-Day Work Task A3	Fri 2/26/10	NA	10 days	10 days	0 days	0 days	0 days
6	5	20-Day Work Task A4	Fri 3/26/10	NA	20 days	20 days	0 days	0 days	0 days
7	6	5-Day Work Task A5	Fri 4/2/10	NA	5 days	5 days	0 days	0 days	0 days
8	7	10-Day Work Task A6	Fri 4/16/10	NA	10 days	10 days	0 days	0 days	0 days
9	**8**	**High-Risk Path Summary Task**	**Fri 4/9/10**	**NA**	**70 days**	**70 days**	**0 days**	**5 days**	**0 days**
10	9	10-Day Work Task B1	Fri 1/15/10	NA	10 days	10 days	0 days	5 days	0 days
11	10	20-Day Work Task B2	Fri 2/12/10	NA	20 days	20 days	0 days	5 days	0 days
12	11	20-Day Work Task B3	Fri 3/12/10	NA	20 days	20 days	0 days	5 days	0 days
13	12	10-Day Work Task B4	Fri 3/26/10	NA	10 days	10 days	0 days	5 days	0 days
14	13	10-Day Work Task B5	Fri 4/9/10	NA	10 days	10 days	0 days	5 days	0 days
15	15	Margin Task	Fri 4/30/10	NA	10 days	10 days	0 days	0 days	0 days
16	16	Program Event No. 1	Fri 4/30/10	NA	0 days	0 days	0 days	0 days	0 days
17	**20**	**Summary Task**	**Fri 6/11/10**	**NA**	**30 days**	**30 days**	**0 days**	**0 days**	**0 days**
18	17	10-Day Work Task C1	Fri 5/14/10	NA	10 days	10 days	0 days	0 days	0 days
19	18	20-Day Work Task C2	Fri 6/11/10	NA	20 days	20 days	0 days	0 days	0 days
20	19	Program Event No. 2 - End of Contract	Fri 6/11/10	NA	0 days	0 days	0 days	0 days	0 days
21	21	Duration Remaining Check	Fri 1/15/10	NA	0 days?	85 days?	85 days?	30 days?	0 days

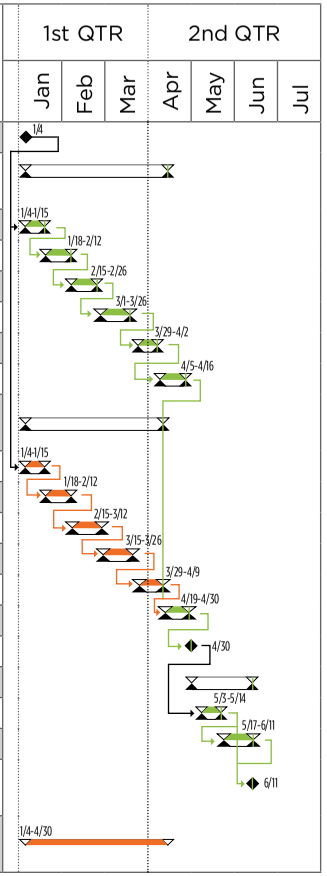


TABLE 1. SCHEDULE METRICS FOR HYPOTHETICAL SCHEDULE

Month of 2010	"Hit-Miss"[a]			BEI[b]			CPLI[c]				
	PT	HT	Index	CT	FT	Index	Index	DR	F+M	SC	SA
January	2	1	0.50	2	2	1.00	1.15	65	10	0	0
February	3	2	0.67	5	5	1.00	1.16	45	7	0	0
March	3	1	0.33	8	6	0.75	1.13	22	3	2	0
April	3	2	0.67	11	9	0.81	1.80	5	4	0	9
May	2			13							
June	1			14							

Note. "Hit-Miss" = "Hit-Miss" Index; BEI = Baseline Execution Index; CPLI = Critical Path Length Index; PT = No. Period Tasks; HT = No. Hit Tasks; CT = No. Cumulative Tasks; FT = No. Finished Tasks; DR = Duration Remaining in Days; F+M = Total Float + Margin in Days; SC = Schedule Compression in Days; SA = Schedule Avoidance in Days. [a]"Hit-Miss": Green ≥ 0.75; Gray ≥ 0.25 and < 0.75; Orange < 0.25. [b]BEI: Green ≥ 0.90; Gray ≥ 0.75 and < 0.90; Orange < 0.75. [c]CPLI: Green ≥ 1.05; Gray ≥ 1.00 and < 1.05; Orange < 1.00.

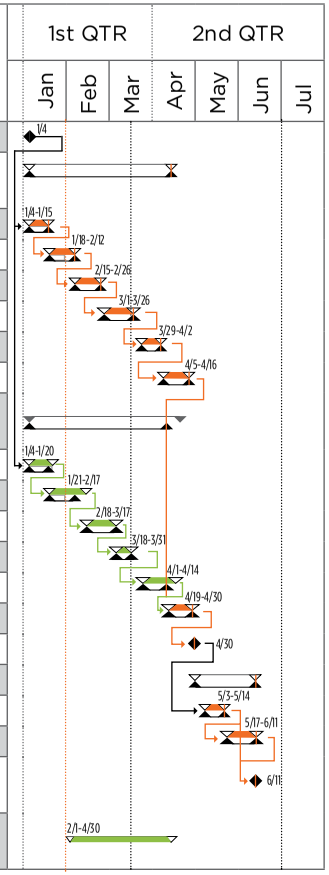
the critical path is the longest path through a network schedule and may not represent the high-risk path. The high-risk string in this schedule has 5 days of total float. To demonstrate the NGA metrics and the CPLI caveats observed on the NGA contract, all tasks associated with the critical path will be completed on schedule, and the high-risk tasks will finish late to demonstrate how the metrics change as the schedule slips. These metrics and their color coding are summarized in Table 1.

NGA Schedule Metrics

Hit-Miss Index, BEI, and CPLI. The January 29, 2010, schedule (Figure 5) and the January 2010 data (Table 1) highlight the basic calculations associated with the NGA schedule metrics. At the end of the first reporting period (January 29, 2010), two tasks were scheduled to be completed and both were completed. Since Task A1 finished on schedule, it counts as a "Hit" for the Hit-Miss index and as a completed task for the BEI. Task B2 finished 3 workdays late, but still during the reporting period so it counts as a "Miss" for the Hit-Miss and as a completed task for the BEI. The Hit-Miss index is 1 ÷ 2 = 0.50, and the BEI is 2 ÷ 2 = 1.00. Although the high-risk path slipped, it has not yet slipped onto the critical path. So the IMS critical path to PE No. 1 is still controlled by the critical path string (0 float days) and the margin task (10 days). The January 29, 2010, schedule task—duration remaining check—shows that 65 workdays

FIGURE 5. JANUARY 29, 2010, SCHEDULE: "HIT-MISS" INDEX, BEI, & CPLI

	Unique ID	Name	Baseline Finish	Actual Finish	Baseline Duration	Duration	Schedule Compression	Float	Slip
1	14	Start Milestone	Mon 1/4/10	Mon 1/4/10	0 days	0 days	0 days	0 days	0 days
2	**1**	**Critical Path Summary Task**	**Fri 4/16/10**	**NA**	**75 days**	**75 days**	**0 days**	**0 days**	**0 days**
3	2	10-Day Work Task A1	Fri 1/15/10	Fri 1/15/10	10 days	10 days	0 days	0 days	0 days
4	3	20-Day Work Task A2	Fri 2/12/10	NA	20 days	20 days	0 days	0 days	0 days
5	4	10-Day Work Task A3	Fri 2/26/10	NA	10 days	10 days	0 days	0 days	0 days
6	5	20-Day Work Task A4	Fri 3/26/10	NA	20 days	20 days	0 days	0 days	0 days
7	6	5-Day Work Task A5	Fri 4/2/10	NA	5 days	5 days	0 days	0 days	0 days
8	7	10-Day Work Task A6	Fri 4/16/10	NA	10 days	10 days	0 days	0 days	0 days
9	**8**	**High-Risk Path Summary Task**	**Fri 4/9/10**	**NA**	**70 days**	**73 days**	**3 days**	**2 days**	**3 days**
10	9	10-Day Work Task B1	Fri 1/15/10	Wed 1/20/10	10 days	13 days	3 days	0 days	3 days
11	10	20-Day Work Task B2	Fri 2/12/10	NA	20 days	20 days	0 days	2 days	3 days
12	11	20-Day Work Task B3	Fri 3/12/10	NA	20 days	20 days	0 days	2 days	3 days
13	12	10-Day Work Task B4	Fri 3/26/10	NA	10 days	10 days	0 days	2 days	3 days
14	13	10-Day Work Task B5	Fri 4/9/10	NA	10 days	10 days	0 days	2 days	3 days
15	15	Margin Task	Fri 4/30/10	NA	10 days	10 days	0 days	0 days	0 days
16	16	Program Event No. 1	Fri 4/30/10	NA	0 days	0 days	0 days	0 days	0 days
17	**20**	**Summary Task**	**Fri 6/11/10**	**NA**	**30 days**	**30 days**	**0 days**	**0 days**	**0 days**
18	17	10-Day Work Task C1	Fri 5/14/10	NA	10 days	10 days	0 days	0 days	0 days
19	18	20-Day Work Task C2	Fri 6/11/10	NA	20 days	20 days	0 days	0 days	0 days
20	19	Program Event No. 2 - End of Contract	Fri 6/11/10	NA	0 days	0 days	0 days	0 days	0 days
21	21	Duration Remaining Check	Fri 1/15/10	NA	0 days?	65 days?	65 days?	30 days?	0 days



remain until the PE No. 1 baseline finish date, resulting in a 1.15 CPLI [(65 + 0 + 10) ÷ 65 = 1.15] for the first reporting period.

CPLI Schedule Caveats

CPLI—duration remaining and total float. The February 26, 2010, schedule (Figure 6) indicates the high-risk path tasks have redefined the schedule's critical path. The February 2010 line entry in Table 1 lists the February 26, 2010, metrics. At the end of the second reporting period, all five tasks scheduled to be completed have been completed, resulting in a 1.00 BEI. Remember that the Hit-Miss index is a current period metric so the 0.67 value represents Task A2 and Task A3 finishing on schedule ("Hit") and Task B2 finishing 8 days late. With 45 days' duration remaining, the schedule's critical path is now defined by the slipping high-risk path tasks. To maintain the April 30, 2010, PE No. 1 baseline finish date, the margin task was reduced from 10 days to 7 days, resulting in a 1.16 CPLI [(45 + 0 + 7) ÷ 45 = 1.16]. Despite the fact that the high-risk path continues to slip, the CPLI showed a slight improvement, thereby demonstrating the need for the duration remaining caveat and total float caveat.

CPLI—schedule compression. The March 26, 2010, schedule (Figure 7) introduces schedule compression and an unfavorable BEI. The March 2010 line entry in Table 1 lists the March 26, 2010, metrics. The high-risk path tasks slipped an additional 6 days in March, and only Task A4 finished on schedule. Neither Task B3 nor Task B4 was completed, resulting in the Table 1 March 2010 Hit-Miss index of 0.33 and BEI of 0.75. If the schedule margin task's duration was reduced for the entire March 26, 2010, schedule slip (6 days), a yellow 1.045 CPLI would result. By compressing the Task B5's schedule by 2 days, the CPLI stays green because the float + margin remain at plus 3 days. This raises an obvious question: Can Task B5 be completed in 8 versus 10 days? It also highlights why schedule compression is a dimension that must be considered when evaluating the CPLI metric.

CPLI—schedule avoidance. The April 23, 2010, schedule (Figure 8) documents the final CPLI schedule caveat observed on the contract. The April 2010 line entry in Table 1 lists the April 23, 2010, metrics. Schedule avoidance occurs when a task is eliminated from the schedule, the IMS network logic is changed to allow a task to be deferred to a later program event milestone, or the IMS logic is changed to allow sequential tasks to be done in parallel. During April 2010, the overall schedule slipped an additional 7 days, making an on-time delivery of PE No. 1 impossible. To support an on-time

FIGURE 6. FEBRUARY 26, 2010, SCHEDULE: CPLI–DURATION REMAINING AND TOTAL FLOAT

	Unique ID	Name	Baseline Finish	Actual Finish	Baseline Duration	Duration	Schedule Compression	Float	Slip
1	14	Start Milestone	Mon 1/4/10	Mon 1/4/10	0 days	0 days	0 days	0 days	0 days
2	**1**	**Critical Path Summary Task**	**Fri 4/16/10**	**NA**	**75 days**	**75 days**	**0 days**	**3 days**	**0 days**
3	2	10-Day Work Task A1	Fri 1/15/10	Fri 1/15/10	10 days	10 days	0 days	0 days	0 days
4	3	20-Day Work Task A2	Fri 2/12/10	Fri 2/12/10	20 days	20 days	0 days	0 days	0 days
5	4	10-Day Work Task A3	Fri 2/26/10	Fri 2/26/10	10 days	10 days	0 days	0 days	0 days
6	5	20-Day Work Task A4	Fri 3/26/10	NA	20 days	20 days	0 days	3 days	0 days
7	6	5-Day Work Task A5	Fri 4/2/10	NA	5 days	5 days	0 days	3 days	0 days
8	7	10-Day Work Task A6	Fri 4/16/10	NA	10 days	10 days	0 days	3 days	0 days
9	**8**	**High-Risk Path Summary Task**	**Fri 4/9/10**	**NA**	**70 days**	**78 days**	**8 days**	**0 days**	**8 days**
10	9	10-Day Work Task B1	Fri 1/15/10	Wed 1/20/10	10 days	13 days	3 days	0 days	3 days
11	10	20-Day Work Task B2	Fri 2/12/10	Wed 2/24/10	20 days	25 days	5 days	0 days	8 days
12	11	20-Day Work Task B3	Fri 3/12/10	NA	20 days	20 days	0 days	2 days	8 days
13	12	10-Day Work Task B4	Fri 3/26/10	NA	10 days	10 days	0 days	2 days	8 days
14	13	10-Day Work Task B5	Fri 4/9/10	NA	10 days	10 days	0 days	2 days	8 days
15	15	Margin Task	Fri 4/30/10	NA	10 days	10 days	0 days	0 days	0 days
16	16	Program Event No. 1	Fri 4/30/10	NA	0 days	0 days	0 days	0 days	0 days
17	**20**	**Summary Task**	**Fri 6/11/10**	**NA**	**30 days**	**30 days**	**0 days**	**0 days**	**0 days**
18	17	10-Day Work Task C1	Fri 5/14/10	NA	10 days	10 days	0 days	0 days	0 days
19	18	20-Day Work Task C2	Fri 6/11/10	NA	20 days	20 days	0 days	0 days	0 days
20	19	Program Event No. 2 - End of Contract	Fri 6/11/10	NA	0 days	0 days	0 days	0 days	0 days
21	21	Duration Remaining Check	Fri 1/15/10	NA	0 days?	45 days?	45 days?	30 days?	0 days

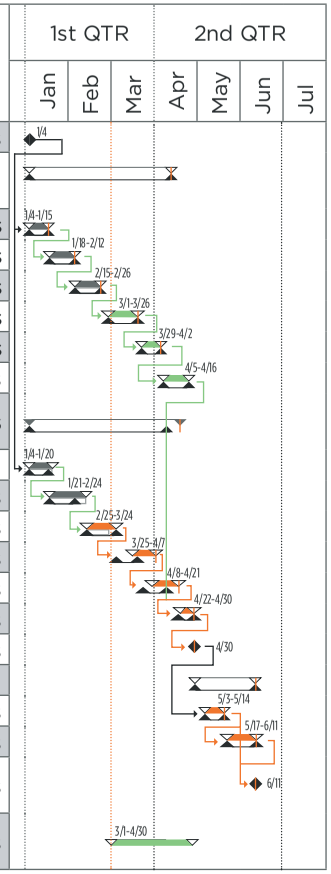


FIGURE 7. MARCH 26, 2010, SCHEDULE: CPLI–SCHEDULE COMPRESSION

	Unique ID	Name	Baseline Finish	Actual Finish	Baseline Duration	Duration	Schedule Compression	Float	Slip
1	14	Start Milestone	Mon 1/4/10	Mon 1/4/10	0 days	0 days	0 days	0 days	0 days
2	**1**	**Critical Path Summary Task**	**Fri 4/16/10**	**NA**	**75 days**	**75 days**	**0 days**	**7 days**	**0 days**
3	2	10-Day Work Task A1	Fri 1/15/10	Fri 1/15/10	10 days	10 days	0 days	0 days	0 days
4	3	20-Day Work Task A2	Fri 2/12/10	Fri 2/12/10	20 days	20 days	0 days	0 days	0 days
5	4	10-Day Work Task A3	Fri 2/26/10	Fri 2/26/10	10 days	10 days	0 days	0 days	0 days
6	5	20-Day Work Task A4	Fri 3/26/10	Fri 3/26/10	20 days	20 days	0 days	0 days	0 days
7	6	5-Day Work Task A5	Fri 4/2/10	NA	5 days	5 days	0 days	7 days	0 days
8	7	10-Day Work Task A6	Fri 4/16/10	NA	10 days	10 days	0 days	3 days	0 days
9	**8**	**High-Risk Path Summary Task**	**Fri 4/9/10**	**NA**	**70 days**	**82 days**	**12 days**	**0 days**	**12 days**
10	9	10-Day Work Task B1	Fri 1/15/10	Wed 1/20/10	10 days	13 days	3 days	0 days	3 days
11	10	20-Day Work Task B2	Fri 2/12/10	Wed 2/24/10	20 days	25 days	5 days	0 days	8 days
12	11	20-Day Work Task B3	Fri 3/12/10	NA	20 days	26 days	6 days	0 days	14 days
13	12	10-Day Work Task B4	Fri 3/26/10	NA	10 days	10 days	0 days	0 days	14 days
14	13	10-Day Work Task B5	Fri 4/9/10	NA	10 days	8 days	-2 days	0 days	12 days
15	15	Margin Task	Fri 4/30/10	NA	10 days	3 days	-7 days	0 days	0 days
16	16	Program Event No. 1	Fri 4/30/10	NA	0 days	0 days	0 days	0 days	0 days
17	**20**	**Summary Task**	**Fri 6/11/10**	**NA**	**30 days**	**30 days**	**0 days**	**0 days**	**0 days**
18	17	10-Day Work Task C1	Fri 5/14/10	NA	10 days	10 days	0 days	0 days	0 days
19	18	20-Day Work Task C2	Fri 6/11/10	NA	20 days	20 days	0 days	0 days	0 days
20	19	Program Event No. 2 - End of Contract	Fri 6/11/10	NA	0 days	0 days	0 days	0 days	0 days
21	21	Duration Remaining Check	NA	NA	0 days?	22 days?	22 days?	30 days?	0 days

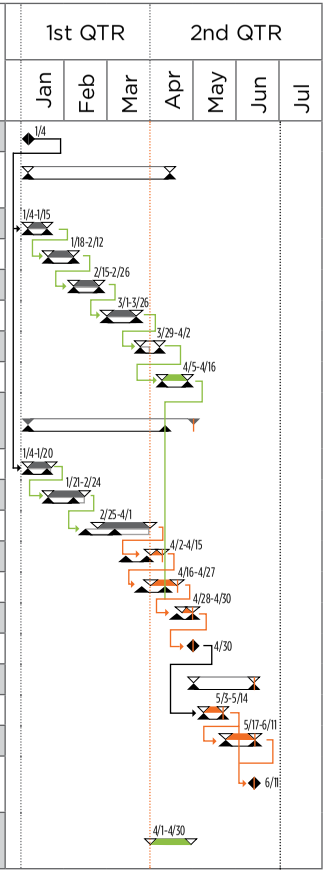
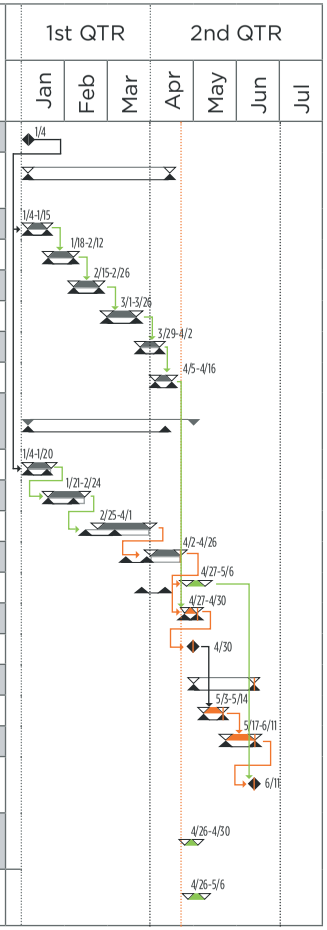


FIGURE 8. APRIL 23, 2010: CPLI—SCHEDULE AVOIDANCE

	Unique ID	Name	Baseline Finish	Actual Finish	Baseline Duration	Duration	Schedule Compression	Float	Slip
1	14	Start Milestone	Mon 1/4/10	Mon 1/4/10	0 days	0 days	0 days	0 days	0 days
2	**1**	**Critical Path Summary Task**	**Fri 4/16/10**	**Fri 4/16/10**	**75 days**	**75 days**	**0 days**	**0 days**	**0 days**
3	2	10-Day Work Task A1	Fri 1/15/10	Fri 1/15/10	10 days	10 days	0 days	0 days	0 days
4	3	20-Day Work Task A2	Fri 2/12/10	Fri 2/12/10	20 days	20 days	0 days	0 days	0 days
5	4	10-Day Work Task A3	Fri 2/26/10	Fri 2/26/10	10 days	10 days	0 days	0 days	0 days
6	5	20-Day Work Task A4	Fri 3/26/10	Fri 3/26/10	20 days	20 days	0 days	0 days	0 days
7	6	5-Day Work Task A5	Fri 4/2/10	Fri 4/2/10	5 days	5 days	0 days	7 days	0 days
8	7	10-Day Work Task A6	Fri 4/16/10	Fri 4/16/10	10 days	10 days	0 days	3 days	0 days
9	**8**	**High-Risk Path Summary Task**	**Fri 4/9/10**	**NA**	**70 days**	**89 days**	**19 days**	**26 days**	**19 days**
10	9	10-Day Work Task B1	Fri 1/15/10	Wed 1/20/10	10 days	13 days	3 days	0 days	3 days
11	10	20-Day Work Task B2	Fri 2/12/10	Wed 2/24/10	20 days	25 days	5 days	0 days	8 days
12	11	20-Day Work Task B3	Fri 3/12/10	Thu 4/1/10	20 days	26 days	6 days	0 days	14 days
13	12	10-Day Work Task B4	Fri 3/26/10	NA	10 days	17 days	7 days	0 days	21 days
14	13	10-Day Work Task B5	Fri 4/9/10	NA	10 days	8 days	-2 days	26 days	19 days
15	15	Margin Task	Fri 4/30/10	NA	10 days	4 days	-6 days	0 days	0 days
16	16	Program Event No. 1	Fri 4/30/10	NA	0 days	0 days	0 days	0 days	0 days
17	**20**	**Summary Task**	**Fri 6/11/10**	**NA**	**30 days**	**30 days**	**0 days**	**0 days**	**0 days**
18	17	10-Day Work Task C1	Fri 5/14/10	NA	10 days	10 days	0 days	0 days	0 days
19	18	20-Day Work Task C2	Fri 6/11/10	NA	20 days	20 days	0 days	0 days	0 days
20	19	Program Event No. 2 - End of Contract	NA	NA	0 days	0 days	0 days	0 days	0 days
21	21	Duration Remaining Check	NA	NA	0 days?	5 days?	5 days?	30 days?	0 days
22	22	Schedule Avoidance Check	NA	NA	0 days?	9 days	9 days?	26 days?	0 days



delivery of PE No. 1, completion of Task B5 is deferred to PE No. 2. This is done by deleting Task B5's task relationship with the schedule margin task and linking it only to the PE No. 2 milestone. Task B5's logic now bypasses PE No. 1, resulting in the avoidance of 9 days of duration remaining, 1 additional day of duration for the margin task, and a very favorable 1.80 CPLI [(5 + 0 + 4) ÷ 5 = 1.80] for PE No. 1. Without the Task B5 schedule avoidance, the PE No. 1 milestone slips 4 days, and the CPLI would be 0.56 = [{9 + (-4) + 0}/ 9]. This highlights why schedule avoidance is a CPLI metric caveat that must be evaluated.

Results and Discussion

The metrics and CPLI caveats discussed hypothetically in this article are computed and documented for the actual program in Tables 2, 3, and 4 at both contract and IMP PE levels. Tables 2, 3, and 4 document the contract schedule metrics for IMP PE-E, PE-F, and PE-G, respectively. The data reflect month 24 for PE-E, and month 25 for PE-F and PE-G. PE-G is the immediate successor event to PE-E and is being completed in parallel with PE-F, which is unrelated. Both PE-G and PE-F are baselined to finish during the first 2 weeks of month 35. The contract-level data tasks only include tasks through day 15 of month 35.

Many conclusions can be drawn from the data contained in Tables 2, 3, & 4 and the IMP strategy used to collect them. Conclusions associated with Table 2 are historic in nature and were confirmed with the NGA program manager and contractor. It is important to note that PE-E was completed on time. This was achieved by deferring some PE-E tasks to PE-G, and by eliminating other PE-E tasks that were not required. In the author's opinion, identification of the deferred and eliminated tasks may not have been discovered using traditional EVM WBS or Organizational Breakdown Structure (OBS) analysis strategies. Applying what the program management team learned from PE-E, pertinent questions arise regarding PE-F and PE-G trends and overall schedule performance. Seven key conclusions supported by this contract's data, metrics, and the IMP analysis strategy follow:

1. Unfavorable schedule trends. In all cases, unfavorable schedule trends are first manifested in the Hit-Miss index, then the BEI, and lastly in the CPLI.
2. Identification of work scope changes. IMP strategy clearly identifies work scope changes. The total number of PE–E tasks gradually increased from 1,109 tasks in month 14 to 1,171

TABLE 2. SCHEDULE METRICS FOR PROGRAM EVENT E

Contract-Level Metrics[a]							Program Event E Metrics[a]									
	"Hit-Miss"[b]			BEI[c]			"Hit-Miss"[b]			BEI[c]			CPLI[d]			
Month	PT	HT	Index	CT	FT	Index	PT	HT	Index	CT	FT	Index	Index	DR	F+M	SC	SA
13	7	1	0.14	45	12	0.27	0	0	0.00	8	4	0.50	1.06	221	12	0	0
14	47	11	0.23	92	40	0.43	27	3	0.11	35	22	0.63	1.11	197	22	0	0
15	65	16	0.24	157	81	0.52	39	7	0.18	74	39	0.53	1.12	177	21	0	0
16	160	40	0.03	317	148	0.47	84	18	0.21	158	88	0.57	1.07	158	11	0	0
17	153	12	0.08	470	202	0.43	76	4	0.05	234	113	0.48	1.06	133	10	0	0
18	226	31	0.13	696	314	0.45	129	15	0.12	363	174	0.48	1.03	113	3	0	0
19	238	66	0.28	934	508	0.54	159	35	0.22	522	277	0.53	1.11	93	10	17	0
20	148	54	0.36	1082	704	0.65	111	36	0.32	633	415	0.66	1.14	70	10	14	0
21	200	74	0.37	1282	925	0.72	123	50	0.41	756	574	0.76	1.04	50	2	11	0
22	207	63	0.30	1489	1130	0.75	79	33	0.42	835	690	0.82	1.00	30	0	3	0
23	297	71	0.27	1773	1492	0.84	61	24	0.39	886	803	0.90	1.00	7	0	73	25
24	169	72	0.42	1942	1573	0.81	12	9	0.75	900	884	0.98	1.00	0	0	0	53

Note. "Hit-Miss" = "Hit-Miss" Index; BEI = Baseline Execution Index; CPLI = Critical Path Length Index; PT = No. Period Tasks; HT = No. Hit Tasks; CT = No. Cumulative Tasks; FT = No. Finished Tasks; DR = Duration Remaining in Days; F+M = Total Float + Margin in Days; SC = Schedule Compression in Days; SA = Schedule Avoidance in Days.
[a]Data based on end of Month 24 schedule. [b]"Hit-Miss": Green ≥ 0.75; Gray ≥ 0.25 and < 0.75; Orange < 0.25. [c]BEI: Green ≥ 0.90; Gray ≥ 0.75 and < 0.90; Orange < 0.75. [d]CPLI: Green ≥ 1.05; Gray ≥ 1.00 and < 1.05; Orange < 1.00.

TABLE 3. SCHEDULE METRICS FOR PROGRAM EVENT F

Contract-Level Metrics[a]							Program Event F Metrics[a]									
	"Hit-Miss"[b]			BEI[c]			"Hit-Miss"[b]			BEI[c]			CPLI[d]			
Month	PT	HT	Index	CT	FT	Index	PT	HT	Index	CT	FT	Index	Index	DR	F+M	SC	SA
22	190	63	0.33	1453	1130	0.78	30	9	0.30	102	63	0.62	1.04	265	11	0	0
23	257	71	0.27	1720	1492	0.87	24	9	0.38	126	96	0.76	1.04	242	11	0	0
24	132	72	0.55	1852	1573	0.85	31	5	0.16	157	117	0.75	1.05	222	11	0	0
25	99	30	0.30	1951	1689	0.87	22	7	0.32	179	143	0.80	0.99	203	-2	0	0
26	107			2058			18			197							
27	182			2240			39			236							
28	191			2431			50			286							
29	306			2737			67			353							
30	401			3138			74			427							
31	365			3503			69			496							
32	296			3799			68			564							
33	211			4010			59			623							
34	108			4118			30			653							
35	54			4172			35			688							

Note. "Hit-Miss" = "Hit-Miss" Index; BEI = Baseline Execution Index; CPLI = Critical Path Length Index; PT = No. Period Tasks; HT = No. Hit Tasks; CT = No. Cumulative Tasks; FT = No. Finished Tasks; DR = Duration Remaining in Days; F+M = Total Float + Margin in Days; SC = Schedule Compression in Days; SA = Schedule Avoidance in Days.
[a]Data based on end of Month 25 schedule. Inconsistencies between Table 2 & Table 3 Contract Level metrics reflect incomplete tasks deleted from baseline during month 25. [b]"Hit-Miss": Green ≥ 0.75; Gray ≥ 0.25 and < 0.75; Orange < 0.25. [c]BEI: Green ≥ 0.90; Gray ≥ 0.75 and < 0.90; Orange < 0.75. [d]CPLI: Green ≥ 1.05; Gray ≥ 1.00 and < 1.05; Orange < 1.00.

TABLE 4. SCHEDULE METRICS FOR PROGRAM G

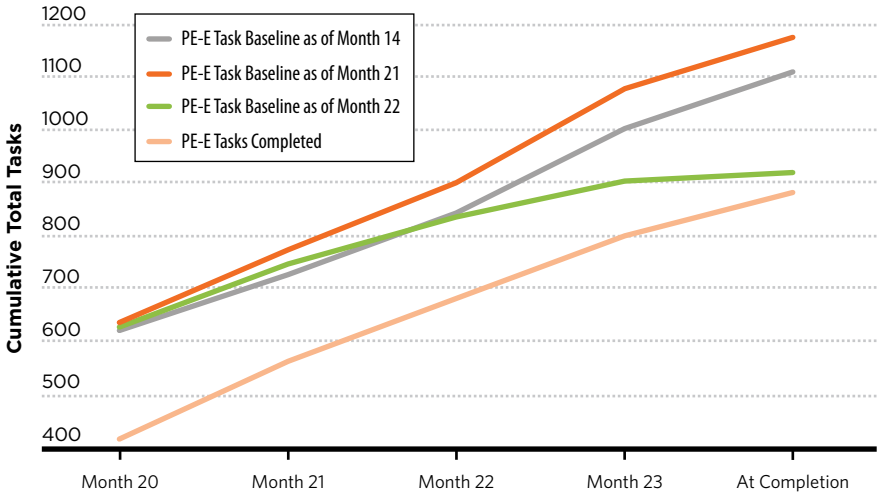
	Contract-Level Metrics[a]						Program Event G Metrics[a]										
	"Hit-Miss"[b]			BEI[c]			"Hit-Miss"[b]			BEI[c]			CPLI[d]				
Month	PT	HT	Index	CT	FT	Index	PT	HT	Index	CT	FT	Index	Index	DR	F+M	SC	SA
22	190	63	0.33	1453	1130	0.78	79	3	0.04	209	70	0.33	1.00	260	0	0	0
23	257	71	0.27	1720	1492	0.87	152	16	0.11	361	128	0.35	1.00	237	0	4	0
24	132	72	0.55	1852	1573	0.85	44	10	0.23	405	182	0.45	1.05	218	10	2	0
25	99	30	0.30	1951	1689	0.87	60	7	0.12	465	249	0.54	1.06	197	12	4	0
26	107			2058			78			543							
27	182			2240			130			673							
28	191			2431			120			793							
29	306			2737			210			1003							
30	401			3138			305			1308							
31	365			3503			267			1575							
32	296			3799			196			1771							
33	211			4010			121			1892							
34	108			4118			54			1946							
35	54			4172			6			1952							

Note. "Hit-Miss" = "Hit-Miss" Index; BEI = Baseline Execution Index; CPLI = Critical Path Length Index; PT = No. Period Tasks; HT = No. Hit Tasks; CT = No. Cumulative Tasks; FT = No. Finished Tasks; DR = Duration Remaining in Days; F+M = Total Float + Margin in Days; SC = Schedule Compression in Days; SA = Schedule Avoidance in Days.

[a]Data based on end of Month 25 schedule. Inconsistencies between Table 2 & Table 4 Contract Level metrics reflect incomplete tasks deleted from baseline during month 25. [b]"Hit-Miss": Green ≥ 0.75; Gray ≥ 0.25 and < 0.75; Orange < 0.25. [c]BEI: Green ≥ 0.90; Gray ≥ 0.75 and < 0.90; Orange < 0.75. [d]CPLI: Green ≥ 1.05; Gray ≥ 1.00 and < 1.05; Orange < 1.00.

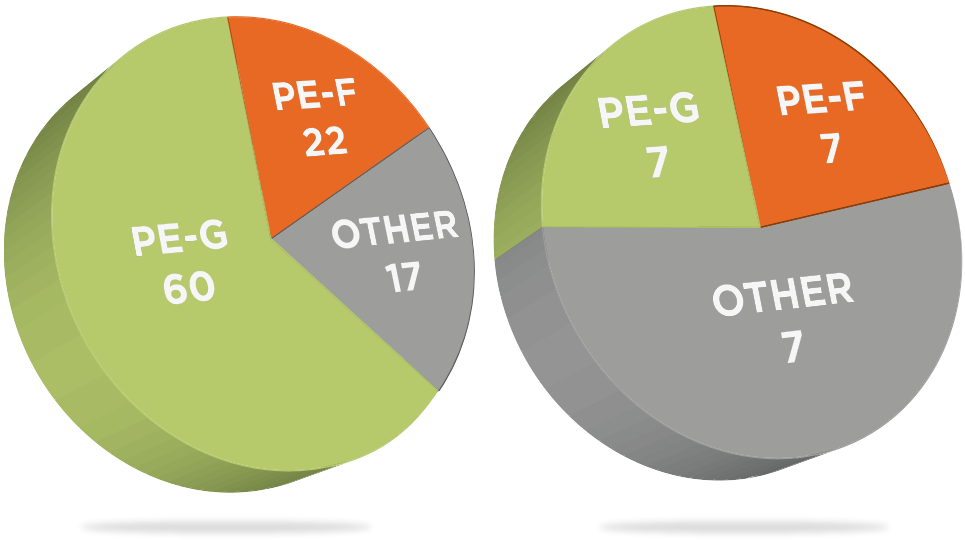
tasks in month 21. The program management team confirmed that these changes resulted from the conversion of EVM planning packages to EVM work tasks, and to the addition of new work resulting from contract changes. In month 22, the total tasks associated with PE-E were abruptly reduced to 924 tasks. The IMP strategy analysis approach clearly identified the descoping, and it was confirmed that the 257 associated tasks were either deferred or eliminated to support PE-E's month 24 delivery date (Figure 9). Additionally, comparing the Table 2 (based on month 24 data) contract cumulative tasks for months 22–24 with the same months on Tables 3 and 4 (based on month 25 data), the program management team can account for the permanent elimination of 90 PE-E tasks from the schedule.

FIGURE 9. PE-E WORK SCOPE CHANGES



3. IMP synergistic planning focus. The IMP structure allows for the current month contract-level tasks to be associated with the current IMP program focus. Tables 3 and 4 and Figure 10 show a total of 99 contract tasks baselined for month 25; 83 percent of these tasks are associated with either PE-F (22 tasks) or PE-G (60 tasks). This leaves 17 current month tasks that are not associated with either of the next two PEs. In and of themselves, the WBS and OBS structures would not easily support this type of assessment.
4. IMP synergistic performance focus. Closely related to conclusion 3, comparing the current month "Contract Tasks Hit" and the corresponding PE-F and PE-G "Hits" task values provides insight on the contract-level metric. Figure 10

FIGURE 10. IMP SYNERGISTIC METRICS



Month 25
Baseline Tasks Scheduled

Month 25
Baseline Tasks Completed

shows 30 of the 99-month, 25 contract-level schedule tasks were completed. Subtracting the 7 Hits from PE-F and the 7 Hits from PE-G leaves 16. So 16 of the 17 tasks not associated with either of the next two milestones were completed. This suggests the contract-level Hit-Miss index by itself may not be a good indicator for assessing PE-F or PE-G progress.

5. BEI measures schedule performance trends. Evaluation of the PE BEI trend can indicate if a schedule is improving. Review of the PE-E (Table 2) BEI metric from month 16 to month 18 indicates the number of cumulative tasks increased at a rate faster than the finished tasks were being completed. The month 16 BEI of 0.57 deteriorated to 0.48 by month 18, indicating a slipping schedule. This fact is also supported by the total float value, which eroded by 8 days during the same period. Like the EVM schedule performance index metric, the BEI eventually must improve to 1.00. This is clearly shown in the BEI improving from 0.48 in month 18 to 0.98 in month 24.
6. CPLI schedule compression an "early" tripwire. Schedule compression was first observed after the PE-E CPLI metric went from green to yellow. In month 18, PE-E's CPLI went from 1.06 (an NGA green value) to 1.03 (an NGA yellow value). In the following month's schedule, the metric returned to green (1.11) when the baseline durations of three future

critical path tasks were reduced by a total of 17 days. In many instances, the schedule compression magnitude was greater on the near-critical path strings than on the critical path string. The author attributes this to control account managers wanting to avoid the extra scrutiny associated with being on the critical path. The EVM COE makes no value judgment on the validity of the schedule compression; as such, the NGA CPLI equation (Figure 3) does not consider it. Schedule compression is a key caveat the program manager must consider when evaluating schedule risk. The author believes schedule compression is a critical indicator of pending schedule issues. In the PE-E schedule, schedule compression was first observed in month 19—3 months before the month 22 adjustment discussed in conclusion 2.

7. CPLI schedule avoidance "too late" tripwire. Schedule avoidance first appeared when it became apparent that PE-E, as it was originally baselined, could not be completed on schedule. During the final 30 workdays leading up to PE-E, 39 tasks originally associated with PE-E were remapped to PE-F. This allowed for the on-time delivery of PE-E. The impact of this can be observed in the month 23 "PT" column (Table 4), which denotes PE-G Tasks Baselined. The contractor confirmed that the disproportionate number of month 23 tasks (152) resulted from tasks being transferred from PE-E. Like schedule compression, the EVM COE does not consider schedule avoidance in the CPLI computation, but does report it as a CPLI schedule metric caveat. The program manager must make the final decision on the potential cost, schedule, and programmatic risk associated with eliminating work scope altogether or deferring work scope to a later IMP PE milestone.

Summary and Concluding Discussion

The EVM COE was challenged to create a set of schedule metrics that provide NGA leadership with accurate assessments of schedule progress. A better understanding of schedule performance and improved program risk identification were realized on this contract when NGA focused its schedule metrics on the IMP structure. While this study's positive results are based on a single contract, they justify additional research with a larger data set. The CPLI caveats qualify the CPLI tripwire metric, which could be easily misinterpreted without them. Considering this finding, additional research is warranted to justify requiring CPLI metric reports to include the caveats. NGA program managers have embraced the IMP structure and the metrics discussed in this article because they are straightforward, focus on near-term problems, and identify specific tasks needed to assess programmatic and schedule risk. This IMP approach, however, does not address cost. The EVM COE found that the IMP structures were so different from the contract's corresponding WBS and OBS structures that EVM cost and schedule data could only be correlated at the total contract level.

NGA has applied the techniques discussed in this article with mixed success on other NGA contracts. When the IMP and schedule margin were well-defined, the resulting schedule metrics were easily computed and meaningful. However, often the required IMP was poorly constructed and schedule margins were ill-defined. Schedule compression and schedule avoidance, to a lesser extent, were observed on many NGA contracts. The 438-page Government Accountability Office (GAO) *Cost Estimating Assessment Guide* lists only three IMP references and contains no discussion on how IMP is to be used (GAO, 2009). The EVM EIA-748B standard does not reference the IMP at all (GEIA, 2007). For the past 6 years, the National Defense Industrial Association (NDIA, n.d.) has identified schedule margin as an unresolved issue (Treacy, 2009; Berkey 2004). The community needs to create an IMP data item description and establish a best practice for implementing schedule margin to universally realize meaningful, straightforward schedule metrics based on this article's IMP approach.

The IMP structure augmented and provided more meaningful metrics for measuring near-term schedule performance then either the WBS or OBS structures; however, integrated program management requires cost, schedule, and performance metrics. This study highlights the value of adding an IMP structure to the IMS. The logical extension of this study would be to also require EVM data be mapped to the IMP structure.

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ENDNOTES

1. Integrated Master Plan (IMP)—The IMP is an event-based plan consisting of a hierarchy of program events, with each event being supported by specific significant accomplishments, and each accomplishment is associated with specific accomplishment criteria to be satisfied for its completion (DoD, 2005a).
2. Program Event—A program event is a program assessment point that occurs at the culmination of significant program activities: significant accomplishments and accomplishment criteria (DoD, 2005a).
3. Significant Accomplishment—A significant accomplishment is the desired result(s) prior to or at completion of a program event that indicates a level of the program's progress (DoD, 2005a).
4. Accomplishment Criteria—Accomplishment criteria provide definitive evidence that a specific significant accomplishment has been completed (DoD, 2005a).
5. Defense Contract Management Agency 14 Point Schedule Assessment—A set of standardized schedule heath and performance metrics used to evaluate integrated master schedules. The metrics included: logic, leads, lags, task relationships, constraints, high float, negative float, high duration, invalid dates, resources, missed tasks, critical path, CPLI, and BEI.
6. Generally Accepted Scheduling Principle (GASP)—A defense industry–Department of Defense initiative to produce valid and effective schedules. To meet GASP tenets, a schedule must be complete, traceable, transparent, statused, predictive, usable, resourced, and controlled.
7. Summary-Level Planning Package (SLPP)—An aggregation of work for far-term efforts, not comprised of detailed planning nor able to be identified at the control account level, which can be assigned to reporting-level WBS elements (DoD, 2006).
8. Schedule Margin—A management method for accommodating schedule contingencies. It is a designated buffer and shall be identified separately and considered part of the baseline. Schedule margin is the difference between contractual milestone date(s) and the contractor's planned date(s) of accomplishment (DoD, 2005b).
9. IMS Schedule Margin—There are differing opinions in the EVM community on the proper use and interpretation of IMS schedule margin[8] (DCMA, 2010; Price, 2008; NDIA, n.d.). Because most NGA contracts include schedule margin strategies, the EVM COE metrics include the use of schedule margin.
10. Float—Also known as total float and total slack. The amount of time a task/activity or milestone can slip before it delays the contract or project finish date (DoD, 2005b).
11. Schedule Compression—Schedule Compression is the difference between a task's baseline duration and the task's current duration. Microsoft Project calls this duration variance (Stover, 2007).
12. Schedule Avoidance—Schedule Avoidance occurs when a task's baseline logic is changed to bypass a measured milestone.
13. Network—A schedule format in which the activities and milestones are represented along with the interdependencies between work tasks and planning packages (or lower level tasks or activities). It expresses the logic (i.e., predecessors and successors) of how the program will be accomplished. Network schedules are the basis for critical path analysis, a method for identification and assessment of schedule priorities and impacts. At a minimum, all discrete work shall be included in the network (DoD, 2005a).

APPENDIX

List of Abbreviations and Acronyms

AT&L	Acquisition, Technology and Logistics
BEI	Baseline Execution Index
CPLI	Critical Path Length Index
DAES	Defense Acquisition Executive Summary
DCMA	Defense Contract Management Agency
DoD	Department of Defense
EIA	Electronic Industries Alliance
EVM	Earned Value Management
EVM COE	NGA Earned Value Management Center of Excellence
GAO	Government Accountability Office
GASP	Generally Accepted Scheduling Principle
GEIA	Government Electronics and Information Technology Association
IBR	Integrated Baseline Review
IMP	Integrated Master Plan
IMS	Integrated Master Schedule
NASA	National Aeronautics and Space Administration
NCE	NGA Campus East
NDIA	National Defense Industrial Association
NGA	National Geospatial-Intelligence Agency
OBS	Organizational Breakdown Structure
PE	Program Event
PMB	Performance Measurement Baseline
WBS	Work Breakdown Structure